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ORIGINAL RESEARCH

THE RELIABILITY AND CONCURRENT VALIDITY OF SHOULDER MOBILITY MEASUREMENTS USING A DIGITAL INCLINOMETER AND GONIOMETER: A TECHNICAL REPORT

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ABSTRACT

Purpose/Aim: This study investigated the intrarater reliability and concurrent validity of active shoulder mobility measurements using a digital inclinometer and goniometer.

Materials/Methods: Two investigators used a goniometer and digital inclinometer to measure shoulder flexion, abduction, internal and external rotation on 30 asymptomatic participants in a blinded repeated measures design.

Results: Excellent intrarater reliability was present with Intraclass Correlation Coefficients (ICC- 3,k) for goniometry ≥ 0.94 and digital inclinometry ≥ 0.95. The concurrent validity between goniometry and digital inclinometry was good with ICC (3,k) values of ≥ 0.85. The 95% limits of agreement suggest that the difference between these two measurement instruments can be expected to range from 2˚ to 20˚.

Conclusions: The results cautiously support the interchangeable use of goniometry and digital inclinometer for measuring shoulder mobility measurements. Although reliable, clinicians should consider the 95% limits of agreement when using these instruments interchangeably as clinically significant differences are likely to be present.

Level of evidence: 2b

Key Words: Goniometry, inclinometry, reliability, shoulder, validity

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INTRODUCTION

The assessment of mobility is an integral component of a physical examination. The examination of joint integrity and mobility is necessary in order to select appropriate physical therapy interventions.[1] Recognizing impairments in joint mobility may assist clinicians in making diagnoses, measuring improvements or deteriorations in mobility, and in determining functional limitations. Therefore, it is essential for clinicians to have reliable and valid measurement instruments in order to objectively monitor disease progression, outcomes, and mobility impairments.

The examination of shoulder mobility may be accomplished using a number of instruments including: visual observation, goniometry, linear measures, and inclinometry.[2] The method and type of assessment will vary among clinicians and institutions based on factors such as time, educational inclination of the clinician, availability of equipment, and the specific movement or tissue being assessed. Goniometry has been used widely due to its portability and low cost.[3,4] However, a limitation of goniometry is that it requires the clinician to use both hands, making stabilization of the extremity more difficult, and thus increasing the risk of error in reading the instrument.[3] Inclinometry is another practical alternative that incorporates the use of constant gravity as a reference point to assess joint mobility.[4-6] Digital inclinometers are portable, lightweight, and require training similar to that of goniometry. However, a disadvantage of digital inclinometry may lie in the fact that it is more costly than conventional goniometers, and requires the examiner to establish the zero point of the digital inclinometer accurately and consistently prior to use in order to minimize the risk of measurement errors.

A recent literature review of shoulder mobility measurements identified comparable use of goniometry and inclinometry among published research investigations; however, no study existed to compare the concurrent validity of goniometry and digital inclinometry.[7] The paucity of research on the interchangeability of these two instruments presents a question as to whether clinicians or researchers can translate findings from a study that used a different instrument with confidence. Specifically, data such as normative values or change scores established with inclinometry may not be valid to a clinician using goniometry and vice versa.

Given the lack of available research investigating the concurrent validity of goniometric and inclinometric measurements of shoulder mobility, further investigation is essential in order to provide clinicians and researchers with the necessary information needed to make clinical decisions regarding their interchangeability. Therefore, the primary purpose of this study was to investigate the concurrent validity of digital inclinometry and goniometry for measuring active shoulder abduction, flexion, internal and external rotation. Additionally, we sought to investigate the intrarater reliability for both instruments.

DESIGN

Participants

Thirty asymptomatic adult participants, 9 males and 21 females, were recruited from a local university setting. Participants who met study requirements were provided with an informed consent document approved by the Institutional Review Board at Nova Southeastern University and all questions were answered to their satisfaction prior to commencing data collection.

Participants completed a questionnaire to report age, height, body mass, and arm dominance. Exclusion criteria consisted of reported cervical spine or upper extremity pain at the time of data collection or recent shoulder surgery on the dominant arm for which the subject was still receiving care. The mean and standard deviation (SD) for the participants' age, body mass, and height were 26 (4.2) years, 70 (11.3) kg, and 170 (8.1) cm respectively. Testing was conducted on the dominant arm. The right arm was dominant in 26 of the 30 participants.

Instruments

A standard plinth and ACUMAR™ digital inclinometer, (Model ACU 360) Lafayette Instrument Company (Lafayette, Indiana) was used for all inclinometric measurements (Figure 1). The manufacturer specifications indicate that this instrument is capable of measuring a range up to 180° with an accuracy of ±1°. A 24 inch bubble level, (model 7724-0, Johnson Level & Tool; Mequon, Wisconsin) was used to zero the inclinometer prior to measurements. A 12-inch plastic BASELINE® goniometer, (Model 12-1000)

Figure 1. *ACUMAR™ Digital Inclinometer, (Model ACU 360) Lafayette Instrument Company: Lafayette, Indiana.*

Fabrication Enterprises (White Plains, New York) was used for all goniometric measurements (Figure 2).

Procedures

Following completion of paperwork and consent, individuals who agreed to participate were brought into a private testing laboratory where they performed a standardized warm-up supervised by the raters who were all third year doctoral physical therapy students. The warm-up required approximately 2 minutes to complete and consisted of ten pendulums both clockwise and counterclockwise as well as ten repetitions of standing shoulder blade squeezes. Each participant was required to perform the same warm-up for consistency; however, to the authors' knowledge there is no benefit or detriment to performing the warm-up.

Following the warm-up, all participants completed the measurements with their dominant arm in an intrasession design. Rater A performed the goniometric measurements and Rater B inclinometric measurements. Prior to taking each of the 4 measurements (flexion, abduction, ER and IR), Rater B passively moved the participant's dominant arm through one repetition in the desired plane up to the point of an end-feel. The purpose of the passive trial repetition was to familiarize the participant with the requested motion. Following the passive trial participants performed each of the four active range of motion (AROM) actions in consecutive order (flexion, abduction, ER and IR) with 1-minute rest intervals between consecutive measurements. For each active repetition, participants were requested to move their arm to end-range and maintain the position while the angle was recorded with the goniometer and inclinometer. Once the measurement was recorded, participants returned their arm to a neutral zero-degree position and the measurement was repeated. Each measurement was obtained twice with the goniometer and twice with the inclinometer before proceeding to the next movement plane. The mean value of the two measurements from each instrument was used for analysis. The raters were blinded to the results, as an independent third person (Rater C) with similar experience in goniometry

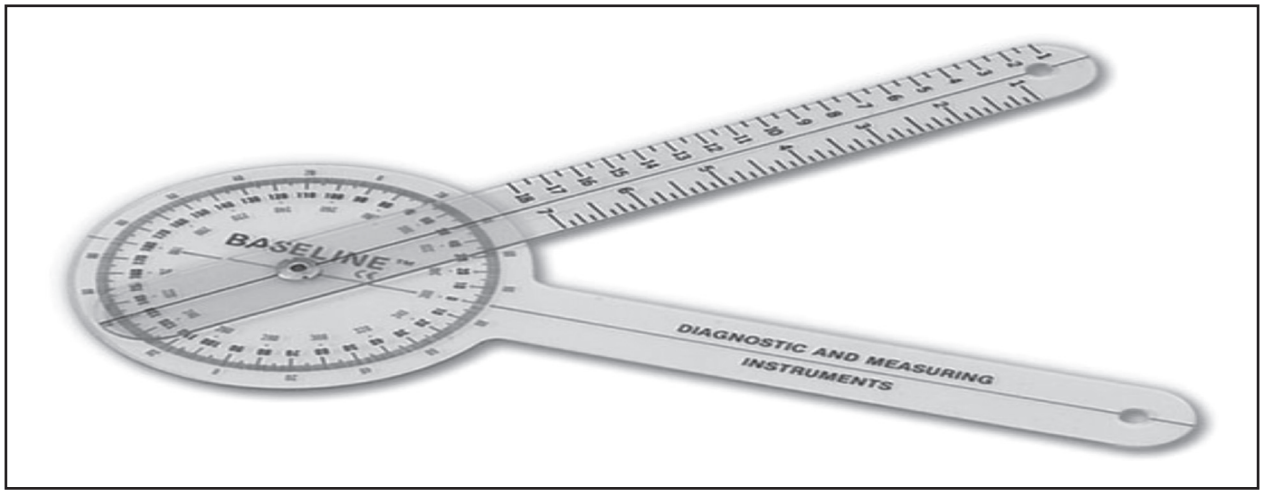

Figure 2. *Standard BASELINE® 12-inch plastic goniometer, (Model 12-1000) Fabrication Enterprises, Inc: White Plains, New York.*

and inclinometry recorded all data. Verbal cues were provided strictly as necessary to ensure proper form during the measurement and to ensure movement was performed to the available end-range.

The procedures for measuring active flexion, abduction, external rotation, and internal rotation followed guidelines established by Clarkson[2] and that have previously been reported in the literature to have good intrarater reliability with intraclass correlation coefficients (ICC) of ≥0.85.[8]

Flexion-AROM was assessed with the participant seated upright in a high back chair and a cloth gait belt secured around their waist (at the level of the umbilicus) and back of the chair to limit trunk compensation. The arm was actively elevated in a strict sagittal plane with the palm down to the participants' end-range ability at which time the measurement was recorded. For inclinometry the instrument was placed on the distal upper arm proximal to the elbow and distal to the glenohumeral joint. The goniometric measurement was taken with the fulcrum placed inferior and lateral to the acromion process, the stable arm parallel to the trunk and the moving arm parallel to the longitudinal axis of the humerus.

Abduction-AROM was measured in the seated chair position, as in flexion, with the trunk upright. The arm was actively elevated in the strict coronal plane with the thumb pointed up toward the ceiling to allow the required external rotation necessary to avoid impingement of the greater tuberosity on the acromion process.[9] Once active end-range was achieved the measurements were documented. For inclinometry, the instrument was placed on the distal arm proximal to the elbow and distal to the glenohumeral joint. The goniometric measurement was taken with the fulcrum placed at the midpoint of the posterior aspect of the glenohumeral joint, the stable arm parallel to the trunk and the moving arm parallel to the longitudinal axis of the humerus.

External rotation-AROM was tested in the supine position with the hips and knees flexed to approximately 45 degrees. The tested arm was supported on the table in 90 degrees of abduction, elbow flexed to 90 degrees, and the wrist in neutral. A towel roll was placed under the humerus to ensure neutral horizontal positioning; which required the humerus to be level to the acromion process based on visual inspection. Once positioned, the participant was asked to rotate their arm back into external rotation to their end available range without discomfort. The participant was instructed not to lift their lower back during this measurement. Once active end-range was achieved the measurement was recorded. The inclinometer was placed on the distal forearm just proximal to the wrist for recording the measurement whereas the goniometric measurement was taken with the stable arm parallel to the floor and the moving arm parallel with the forearm.

Internal rotation-AROM was measured in the prone position with the tested arm supported on the table in 90 degrees of abduction, the forearm flexed to 90 degrees, and the wrist in neutral. A towel roll was placed directly under the arm to ensure neutral horizontal positioning and to provide stabilization. The participant was instructed to internally rotate their arm while maintaining the 90 degree abducted position. The tester carefully monitored participants to avoid compensatory scapular movement through verbal cues. Manual cues were provided as necessary if the participant did not maintain the required testing position on the first attempt. Manual cues were required for 4 participants to keep their arm in the 90-degree abducted position; however, the prone position was chosen as it did prevent anterior tilting of the scapula at end-range. Once active end-range was achieved the measurement was recorded. The inclinometer was placed on the distal forearm just proximal to the wrist for recording the measurement, whereas goniometric measurements were taken with the stable arm parallel to the floor and the moving arm parallel with the forearm.

The measurements required approximately 30-minutes from the initiation of the warm-up to completion. Raters remained blinded to both their results as well as the other rater's results throughout the investigation.

STATISTICAL METHODS

Data analysis was performed with SPSS version 15.0 for Windows. Descriptive data including mean measurement angles with standard deviations (SD) were calculated for each session. The intrarater reliability was determined by the ICC Model 3, k. The mean value from each testing session was used for the analysis. Model 3, k was used for the intrarater analysis because the specific rater was the only

Table 1. *Descriptive Measurement Data.*

	Flexion Mean° (SD)	Abduction Mean° (SD)	Ext. Rotation Mean° (SD)	Int. Rotation Mean° (SD)
Goniometer	156(9)	161(11)	92(10)	48(10)
Inclinometer	164(9)	162(11)	100(11)	43(10)

SD= standard deviation; Ext= external; Int= internal.

Table 2. *Intrarater Reliability of Goniometer and Inclinometer.*

	Flexion	Abduction	Ext. Rotation	Int. Rotation
Goniometer				
ICC (95% CI)	0.95(0.89-0.98)	0.97(0.94-0.99)	0.94(0.87-0.97)	0.95(0.89-0.98)
SEM°	2°	2°	3°	2°
Inclinometer				
ICC (95% CI)	0.95(0.90-0.98)	0.97(0.94-0.98)	0.98(0.96-0.99)	0.97(0.93-0.98)
SEM°	2°	2°	2°	2°

ICC= intraclass coefficient; SEM= standard error of measurement rounded to nearest degree; CI=Confidence interval; Ext= external; Int= internal

tester of interest.[10,11] Interpretation of ICC values was based on guidelines offered by Portney and Watkins,[10] where a value above 0.75 was classified as good reliability. ICC values may be influenced by intersubject variability of scores, because a large ICC may be reported despite poor trial-to-trial consistency if the intersubject variability is too high.[10,12] The standard error of measurement (SEM) is not affected by intersubject variability.[12] Therefore, SEM was reported in conjunction with the ICC's using the formula: $SEM = SD\sqrt{1-r}$.[10] An ICC Model 3, k was used in the concurrent reliability analysis to determine if both methods of measurement analysis produced comparable results. ICC value interpretations were based on the aforementioned guidelines established by Portney and Watkins.[10] The 95% limits of agreement (LOA) were calculated using the formula: 95% limits of agreement = mean difference +/- 2SD.[10]

RESULTS

Descriptive data, including the mean and SD for each of the four measurements are presented in Table 1. Intrarater analysis suggested excellent reliability for all measurements with both instruments ranging from, ICC (3,k) =0.94-0.98. There was a trend for higher reliability with the inclinometric measurements when compared to goniometry. Measurement data from the intrarater reliability analysis including the ICC, 95% CI and SEM are presented in Table 2. The concurrent validity between goniometry and digital inclinometry measurements are presented in Table 3. When comparing the mean end-range angles for the instruments a trend existed for lower goniometric values of flexion, abduction and external rotation compared to inclinometry. The mean goniometric value of internal rotation, however, was greater than the mean inclinometric value. In regards to agreement the 95% LOA suggests that goniometry may range from being 20° less than to 5° greater than inclinometry when measuring flexion. The 95% LOA suggests that goniometric abduction may range from 17° less

Table 3. *Concurrent Reliability of Goniometry and Digital Inclinometry.*

Measurement	ICC(3,k)	95% CI
Flexion	0.86	0.71-0.94
Abduction	0.85	0.69-0.93
Ext. Rotation	0.97	0.94-0.99
Int. Rotation	0.95	0.89-0.96

ICC= Intraclass Correlation Coefficient; CI= Confidence interval; Ext= external; Int= internal.

than to 14° greater than inclinometry. Goniometric external rotation may range from 2-16° less than inclinometry, whereas internal rotation measurements ranged from 3- 15° greater than inclinometry.

DISCUSSION

When adhering to the procedures outlined in this investigation, measurements taken using both the inclinometer and goniometer possessed good intrarater reliability. The reliability results are comparable to previous research which has reported the good to excellent intrarater reliability when utilizing similar measurement procedures.[8]

In regards to concurrent validity, measurements with a digital inclinometer were found to be comparable to those taken with the standard 12-inch plastic goniometer with ICC values ≥ 0.85. Also, there was a trend for inclinometric measurements being greater than goniometry for flexion, abduction and external rotation. In contrast, goniometric internal rotation measurements had a greater mean measurement angle than inclinometry. The mean differences in measurements between the instruments were the greatest for external rotation and flexion and had the narrowest range for abduction. There was no identifiable systematic error in technique that could explain the differences. One might surmise that Rater A (who took all goniometric measurements) was biased toward lower angles, however, internal rotation was higher from Rater A which challenges that assumption. Furthermore, the landmarks for measurements are different which may produce different end-ranges and should be of concern to clinicians. Unfortunately, no studies have established the validity of these instruments concurrently with radiography to determine which one might offer a more valid estimate of mobility. Clinicians and researchers should recognize that the difference between these two measurement instruments can be expected to vary by 2°- 20° with differences dependent upon the movement being measured. From a clinical perspective this cannot be overlooked as the upper range of disagreement at 20 degrees may lead to differences in both diagnosis and the plan or care particularly as related to interventions designed to improve mobility.

Only two previous studies have investigated the concurrent validity of similar instruments for measuring shoulder function. One study investigated the concurrent validity of scapular plane elevation using similar instruments to this investigation.[13] In the aforementioned study the concurrent validity was good with an ICC value of 0.94 and the 95% LOA suggesting that the difference between these two measurement instruments can be expected to vary by up to +/- 11°. Another study investigated the concurrent validity of goniometry and a construction grade digital level and reported ICC values of non-involved (asymptomatic) to involved (symptomatic) shoulder motions of flexion, ER and IR.[14] In the aforementioned study the concurrent validity was reported to range from ICC = 0.71-0.98 for both non-involved and symptomatic shoulders. For shoulder flexion the ICC ranged from 0.91-0.95 for the involved shoulder compared to 0.81-0.86 for the uninvolved. ER ranged from 0.91-0.96 (involved) to 0.71- 0.94 (uninvolved) whereas IR ranged from 0.82-0.96 (involved) to 0.83-0.93 (uninvolved).[14] While the aforementioned study offers insight into the interchangeability, the construction-grade digital level may not be comparable to traditional inclinometers such as the one used in this investigation.

This study was the first to analyze the concurrent validity of goniometric and digital inclinometric measurements of shoulder mobility. Due to the lack of research in this area, a comparison between the current study and previous research cannot be made. However, this study does set the groundwork for further research in this area in order to evaluate the interchangeability of goniometric and digital inclinometric measurements.

LIMITATIONS AND FUTURE RESEARCH

When interpreting the reliability values in our investigation, one must recognize that the consistency of AROM in individuals with healthy shoulders may not correlate with those who have shoulder pathology. Triffitt et al[15] assessed the reproducibility limits of inclinometric shoulder abduction and external rotation in both symptomatic and asymptomatic subjects. Asymptomatic subjects had a difference ranging from 24 to 33° for all measurements as compared to 24 to 41° in symptomatic subjects, suggesting a greater variance among those with a painful shoulder. While the authors of the current study cannot state with certainly that this would be the case with all testers and procedures it is an issue requiring consideration.

Additionally, when studying a symptomatic population, the ability of an individual to achieve and maintain their arm in a specific plane may be compromised secondary to restrictions in joint mobility and/or pain. Moreover, this investigation required participants to hold their end-range for a time period that allowed two measurements (inclinometry and goniometry) to be performed which may not have been possible in a symptomatic cohort. Lastly, the participants in this investigation consisted of a young, college-aged population (mean age = 26). The average age of individuals seen in the clinical setting is 44 years.[16] Therefore, the current results may not necessarily be generalized to a sub-group with increasing or decreasing age.

When comparing instruments such as goniometry and inclinometry it is important to consider limitations to both instruments. The inclinometer uses a fixed vertical reference point realized by gravity, thus is stable provided the zero point is accurately calibrated and established. Traditional goniometry requires visualization of the vertical reference point, which may compromise measurement reproducibility. Another issue that warrants discussion is the potential effect of body types (ectomorphs versus endomorphs and mesomorphs) on digital inclinometer measurements. The inclinometer measurements of shoulder flexion and abduction were taken at the midline of the humerus on the superior portion of the biceps brachii. Ectomorphic body types tend to have a linear frame with sparse muscular development whereas, mesomorphs and endomorphs have a greater amount of tissue surrounding their frame.[17] Digital inclinometer measurements may differ from goniometric measurements due to the differences in tissue mass.

Lastly, the mean values of flexion and abduction obtained in this study may be less than that obtained in a clinical setting or reported in examination textbooks. The difference in values is most likely the result of adherence to strict measurement planes in this investigation. Following strict measurement protocols prevents compensatory movements that may allow higher ranges to be measured. Although the raters had limited clinical experience they were intentionally following a research protocol that was practiced thus experience does not appear to have had an effect on the mobility values.

CONCLUSION

This investigation is the first of its kind to evaluate the reliability and concurrent validity of digital inclinometric and goniometric measurements of active shoulder flexion, abduction, external and internal rotation. When used with the measurement procedures outlined in this investigation, both techniques are reliable, as evidenced by reliability coefficients that exceed 0.90 (the threshold recommended for making clinical decisions).[10] Good concurrent validity statistics were produced; however, one should recognize the potential ranges of disagreement between the two measurement instruments used in this study. When monitoring or comparing active shoulder mobility measurements both researchers and clinicians should consider using similar instruments.

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